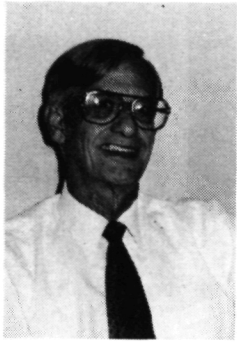


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Dr. Siler received his M.S. degree in fluid dynamics from Stevens Institute of Technology and his Ph.D. in biology from City University of New York. He is a senior research associate at the Mote Marine Laboratory in Sarasota, Florida (since 1987). From 1959 to 1965, Dr. Siler was supervisor of the computer facility and radiological physics section at Memorial Sloan-Kettering Cancer Center in Birmingham, Alabama. He was an associate professor and chairman of the Biomedical Computer Science Program at Downstate Medical Center from 1965 to 1972; professor and chairman of the biomathematics department at the University of Alabama at Birmingham from 1972 to 1980; and director of clinical computing at Carraway Methodist Medical Center in Birmingham from 1980 to 1987. From 1970 to 1974, Dr. Siler was a member of the computer and biomathematical sciences study section of the National Institute of Health. He was Data Processing Professional of the Year of the Data Processing Managers' Association in 1981, and a member of the Biostatistics and Epidemiology Contract Review Committee of the National Cancer Institute from 1981 to 1985 - serving the committee as chairman from 1984 to 1985.

FLOPS: A PARALLEL-RULE-FIRING FUZZY EXPERT SYSTEM SHELL

Abstract

The use of fuzzy systems theory as a basis for expert systems is reviewed with particular reference to a fuzzy expert system having rules that are fired in parallel. Examples are given of fuzzy sets, fuzzy numbers, and fuzzy logic, and their use in pattern recognition and process control. Fuzzy systems theory may be looked upon as furnishing ways of processing information which is uncertain, imprecise, vague, ambiguous, or contradictory. This paper is concentrated on the use of fuzzy systems theory in processing information which is ambiguous or contradictory, rather than uncertain, vague, or imprecise. We also show how advantages can be reaped from the intentional introduction of ambiguities in description, even in a field as objective as process control.

**FLOPS - A GENERAL-PURPOSE
FUZZY EXPERT SYSTEM SHELL**

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PROCEDURAL LANGUAGES (FORTRAN, PASCAL C)

and

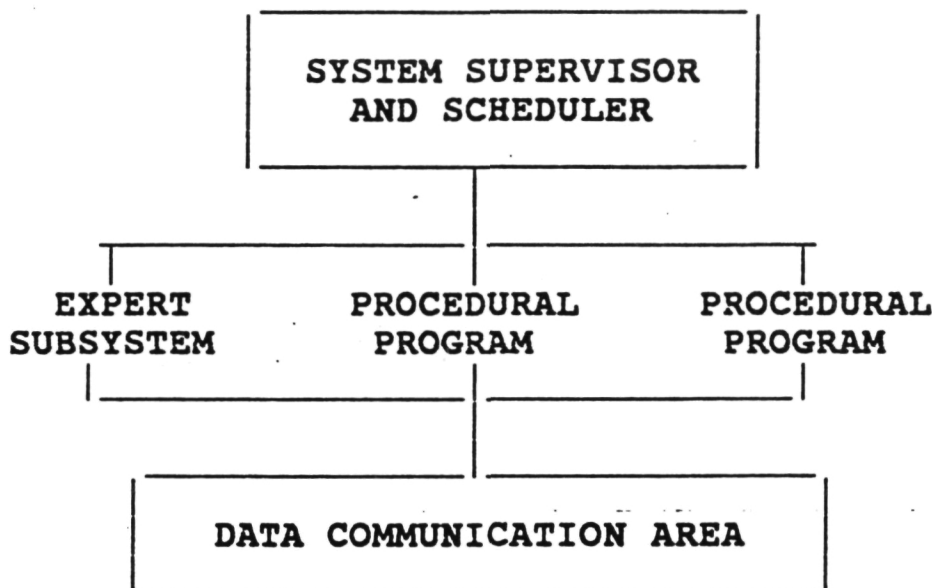
NON-PROCEDURAL LANGUAGES (EXPERT PRODUCTION SYSTEMS)

Advantages and Disadvantages for Problem Solving:

	PROCEDURAL	NON-PROCEDURAL
Speed	Fast	Very Slow
Numerical Computation	Very Good	Very Bad
Symbolic Computation (Reasoning)	Poor	Excellent

Best power obtained from a mix of procedural and non-procedural languages

BLACKBOARD EXPERT SYSTEM FRAMEWORK



BLACKBOARD SYSTEM PERMITS COMBINING ADVANTAGES OF BOTH PROCEDURAL AND NON-PROCEDURAL LANGUAGES.

REQUIREMENTS:

Expert system should be able to call programs or systems in any other language; control should revert to expert system on program or system termination.

A flexible common framework should be chosen for data, so the programs can communicate effectively and conveniently with each other.

Few expert system shells meet these requirements.

HANDLING UNCERTAINTIES

Candidate Methods:

Ad hoc methods (e.g. Mycin, M1)

Bayes' Theorem (e.g. Prospector derivatives)

Dempster-Shafer Theory

Fuzzy Systems Theory

HANDLING AMBIGUITIES:

An ambiguity: the situation when more than one of several possibilities might be true.

A Contradiction: only one of several possibilities is true, but we don't know which one.

Candidate Methods:

Ad hoc methods (virtually non-existent)

Probability distributions (theoretically possible, but very awkward and seldom if ever done)

Fuzzy Systems Theory (extremely easy)

EXAMPLES OF A FUZZY SET:

ATHLETES IN MASH 4077

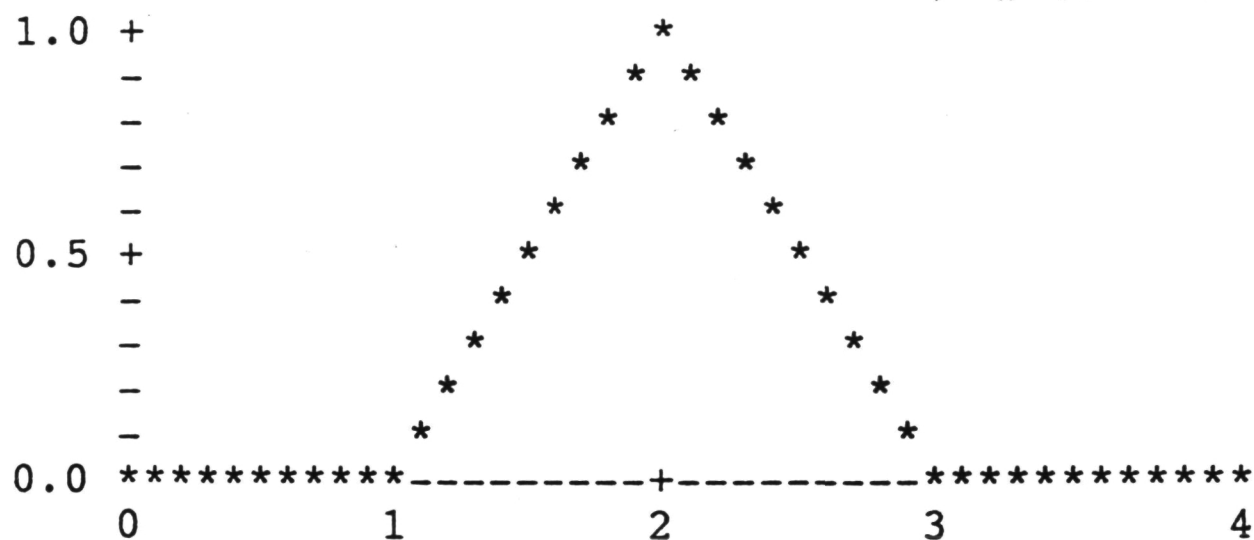
<i>Member</i>	<i>Grade of Membership</i>
Lt. Col. Penobscot	1.0
Father Mulcahey	0.8
Major Houlihan	0.6
B. J. Honeycutt	0.5
Klinger	0.4
Hawkeye Pierce	0.15

OBJECTS ON A RADAR SCREEN

<i>Member</i>	<i>Grade of Membership</i>
Commercial Airliner	0.02
Military Jet	0.01
Light Plane	0.13
Powered Ultralight	0.44
Hang Glider	0.63
Santa Claus	0.99

EXAMPLE OF A FUZZY NUMBER: A FUZZY TWO

Grade of
Membership



Member

EXAMPLE OF FUZZY LOGIC:

My talk will be a success if the material is interesting, the visual material good and the audience is really interested or if the talk is given by a very exciting speaker.

```
Rule 1: ( ( Material = interesting
           AND
           visuals = good
           AND
           audience = interested )
         OR
         ( speaker = exciting )
         -->
         talk = success
```

Confidence that (material = interesting) = 0.75

Confidence that (visuals = good) = 0.6

Confidence that (audience = interested) = 0.88

Confidence that (speaker = exciting) = 0.33

Combined confidence:

first clause, $\min(0.75, 0.6, 0.88) = 0.6$

second clause = 0.33

first OR second clause, $\max(0.33, 0.60) = 0.60$

(AND Rule: A chain is no stronger than its weakest link.)

APPLICATION: PATTERN RECOGNITION

General Scheme:

1. Feature extraction by procedural language programs.
2. Assign word descriptors to features using fuzzy sets to handle ambiguities.
3. Assign preliminary classifications using fuzzy sets to handle contradictions.
4. Resolve contradictory preliminary classifications to obtain final classifications. Usually means pulling in additional information as required.

ASSIGNING WORD DESCRIPTORS TO NUMERIC FEATURES:

AREA of image region to be classified = a numeric feature

SIZE of image region is a fuzzy set of word descriptors:

SIZE = {TEENY SMALL MEDIUM LARGE HUGE}

RULE (in English): if for any region the AREA is approximately less than or equal to a fuzzy 100 plus or minus 50 then the SIZE is TEENY.

In FLOPS:

```
rule ( region ^area ~<= 100,50,0 )  
    --> modify 1 ^size.TEENY ;
```

Other descriptors:

xbar = numeric feature,
xpos = {FAR_LEFT LEFT CENTER RIGHT FAR_RIGHT} = fuzzy set

ybar = numeric feature,
ypos = {HIGHEST HIGH MIDDLE LOW LOWEST} =fuzzy set

CLASSIFICATION RULES:

Classification fuzzy set used in echocardiogram classification:

```
class = {LV RV LA RA LV+LA RV+RA ARTIFACT PAPILLARY  
...}
```

RULE (in English) If in any region the size is SMALL and the x-position is CENTER and the y-position is HIGHEST then it is likely to be an ARTIFACT.

In FLOPS:

```
rule ( region ^size.SMALL ^xpos.CENTER  
        ^ypos.HIGHEST )  
    -->  
    modify 1 ^class.ARTIFACT ;
```

MATCHING OBSERVED PATTERN AGAINST LIBRARY PATTERN

For illustration, we match only one fuzzy set, that for **size**. In general, more than one fuzzy set would be simultaneously matched.

Fuzzy Set Size:

	Observed	Pattern_1	Observed AND Pattern_1
Member	Grade-Of-Membership	Grade-Of-Membership	Grade-Of-Membership
Very Large	0	0.15	0
Large	0.04	1.00	0.04
Medium	1.00	0.45	0.45
Small	0.65	0	0
Very Small	0	0	0

Confidence in match = match on Very Large OR Large OR
....

= $\max(0, 0.04, 0.45, 0, 0)$

= 0.45

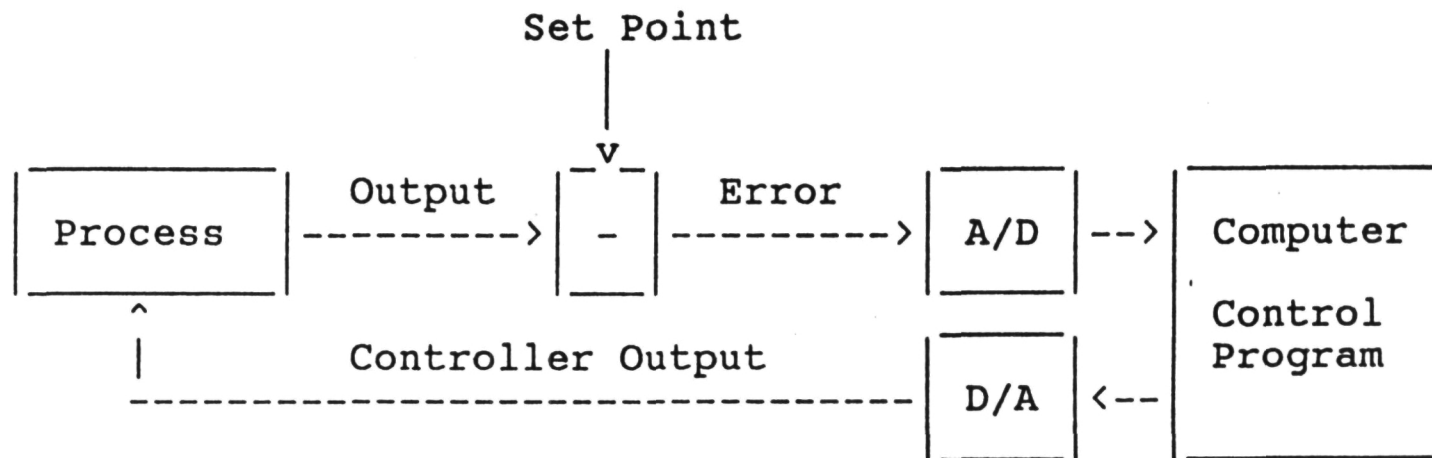
= grade of membership of PATTERN_1 in fuzzy set of
classifications.

(We are on our way toward a simple and reliable
pattern-matching technique, making use of the
ambiguities in the word descriptor fuzzy sets.)

FUZZY PROCESS CONTROL

Especially useful when we do not have a mathematical model of the process.

Block Diagram:



SIMPLE PROCESS CONTROL PROGRAM:

1. Convert error, rate of change of error to fuzzy set of word descriptors such as NEGATIVE_SMALL, POSITIVE_LARGE (fuzzification).
2. Use control rules to obtain fuzzy set of word descriptors for controller output.
3. Convert fuzzy set for controller output to voltage (defuzzification).

Typical control rules:

IF error is POSITIVE_SMALL and rate is ZERO then
controller-output is NEGATIVE_SMALL.

In FLOPS:

```
rule ( process ^error.P_SMALL ^rate.ZERO )  
      ( controller )  
      -->  
      modify 2 ^output.N_SMALL ;
```

FLOPS: A FUZZY EXPERT SYSTEM SHELL.

Features:

(1) Deductive reasoning is emulated by a conventional sequential-rule-firing mode; inductive reasoning is emulated by a unique parallel-rule-firing mode which in turn emulates a non-von-Neumann parallel computer.

(2) Data types include integers; floats; strings; fuzzy numbers; fuzzy sets and confidence levels.

(3) Two external file types are provided: Type I, FLOPS programs and commands; and Type II, "flat file" relational data base format.

(4) External programs written in any language may be called in the same manner as a DOS call: program name plus command string. With (3), provides a blackboard system.

(5) A basic truth maintenance system is provided based on monotonic fuzzy logic; this may be overridden by the programmer to provide fully non-monotonic logic.

(6) Backtracking is fully automatic in sequential mode. Since in parallel mode all fireable rules are fired concurrently, backtracking is irrelevant.

SUMMARY

(1) Fuzzy systems theory permits handling uncertainties, ambiguities and contradictions in a mathematically convenient and rigorous fashion. It may be used both in procedural and non-procedural languages. When employed in an expert system, a system shell should be written or selected which incorporates these basic features:

- Confidence factors for strings, floats and integers;
- Discrete fuzzy sets;
- Fuzzy numbers;
- Approximate numerical comparison operators.

(2) Although expert production systems are too slow to permit their unassisted use in most online applications, they may be used in conjunction with procedural language programs in a blackboard system to combine the reasoning skills of an expert system with the computational ability of procedural language programs.

(3) While fuzzy techniques are very powerful, they are unfamiliar to most American engineers and scientists. Study and practice in their use is required.